Charmonium Suppression with $c\bar{c}$ Dissociation by Strings*

J. Geiss, C. Greiner, E. L. Bratkovskaya, W. Cassing and U. Mosel
Institut für Theoretische Physik, Universität Giessen
D-35392 Giessen, Germany

Abstract

We study the production of $c\bar{c}$ pairs in nuclear reactions at SPS energies within the covariant transport approach HSD. The production of $c\bar{c}$ is treated perturbatively employing experimental cross sections while the interactions of $c\bar{c}$ pairs with baryons are included by conventional cascade-type two-body collisions. Adopting 6 mb for the $c\bar{c}$-baryon cross sections the data on J/Ψ suppression in p + A reactions are reproduced in line with calculations based on the Glauber model. Additionally the dissociation of the $c\bar{c}$ pairs by strings is included in a purely geometrical way. We find good agreement with experimental data from the NA38 and NA50 collaboration with an estimate for the string radius of $R_s \approx 0.2 - 0.3\, fm$.

*Supported by BMBF and GSI Darmstadt

1 Introduction

The J/Ψ suppression has been proposed as one of the signals for the quark-gluon plasma (QGP) which is expected to be formed in nucleus-nucleus collisions at sufficiently high energies [1]. This suggestion has stimulated a number of experiments, which indeed have observed a significant reduction of the scaled J/Ψ yield when going from proton-nucleus to nucleus-nucleus reactions [2]. Especially the NA50 experiment has reported an abrupt decrease in J/Ψ production in Pb + Pb collisions at 158 GeV per nucleon [3, 4, 5] in going from peripheral to central collisions.

A lot of theoretical effort has been spent to understand the experimental results (see [6] for a recent review). Beside the suggestion of a possible formation of a QGP [7, 8, 9] various scenarios based on J/Ψ absorption by hadrons have also been proposed [10, 11, 12, 13, 14, 15]. A part of the suppression can be explained by J/ψ–absorption on the surrounding nucleons [10], additional absorption might be attributed to 'comovers' ('mesons') being produced as secondaries [11, 12]. It has been shown in [14] within the microscopic covariant transport approach HSD (Hadron String Dynamics) [16] that the observed suppression of the J/Ψ yield in nuclear collisions is consistent with such an hadronic absorption scenario. However, the 'comover' models are still a matter of debate: The employed absorption cross section of $c\bar{c}$ pairs on comovers of 3 mb is treated as a free parameter in order to explain the data. On the other hand, this cross section might be overestimated considerably [17].

In our present work we therefore consider an alternative mechanism for J/Ψ production in heavy ion collisions. We will focus on the effect of $c\bar{c}$ dissociation in the prehadronic phase and not on absorption by comovers. This is motivated by the fact, that the very early collision phase is not described by hadrons but by highly excited strings, which in the HSD model are created by momentum transfer among target and projectile nucleons . Their production and decay is treated within the FRITIOF model [18] and describes the first few fm/c of the collision. The $c\bar{c}$ state, most likely as a color octet, is also produced at the earliest state of the reaction in a hard collision among the nucleons via gluon-gluon fusion. Hence it is natural to ask what happens if this colored state moves into such a temporary environment of strings. As the string carries a lot of internal energy (to produce the later secondaries) in a small and localized space-time volume the quarkonia state might get completely dissociated by the intense color electric field inside a single string. In this respect Loh et. al. [19] have investigated the possible J/Ψ dissociation in a color electric flux tube in a semiclassical model based on the Friedberg-Lee color dielectric Lagrangian. They find that the $c\bar{c}$ state becomes dissociated rather immediately on a timescale less than 1 fm/c. In a heavy ion collision, especially for the more heavy systems, the effective region (or volume) of all the strings being produced is expected to be large so that the strings might become rather closely packed. If the $c\bar{c}$ states will get dissociated by the numerous and individual strings this will lead to an additional suppression of J/Ψ in the early phase prior to hadronization. To explore this intuitive idea we include the effect of $c\bar{c}$ dissociation by strings into the HSD model and study the overall J/Ψ production and dissociation dynamically.

The HSD model is briefly presented in section 2, while in section 3 we describe the $c\bar{c}$ production process and show details of the string evolution in the HSD model. We

then address the dissociation process of the $c\bar{c}$ states on baryons and the chromoelectric flux tube of the strings (section 4). We conclude with a summary of our investigations.

2 The covariant transport approach

In this work we perform our analysis along the line of the HSD approach [16] in the cascade modus which is based on a coupled set of covariant transport equations for the phase-space distributions $f_h(x,p)$ of hadron h [16], i.e.

$$\begin{aligned}
&\left(\frac{\partial}{\partial t} + \frac{\vec{p}_1}{m}\vec{\nabla}\right) f_1(x,p_1) \\
&\quad = \sum_{2,3,4\ldots} \int d2d3d4\ldots [G^\dagger G]_{12\to 34\ldots}\delta^4(p_1^\mu + p_2^\mu - p_3^\mu - p_4^\mu \ldots) \\
&\quad \times \Big\{ f_3(x,p_3) f_4(x,p_4) \bar{f}_1(x,p) \bar{f}_2(x,p_2) \\
&\quad - f_1(x,p) f_2(x,p_2) \bar{f}_3(x,p_3) \bar{f}_4(x,p_4) \Big\} \ldots \quad .
\end{aligned} \tag{1}$$

Here $[G^\dagger G]_{12\to 34\ldots}\delta^4(p_1^\mu + p_2^\mu - p_3^\mu - p_4^\mu \ldots)$ is the 'transition rate' for the process $1+2 \to 3+4+\ldots$, while the phase-space factors

$$\bar{f}_h(x,p) = 1 \pm f_h(x,p) \tag{2}$$

are responsible for fermion Pauli-blocking or Bose enhancement, respectively, depending on the type of hadron in the final/initial channel. The dots in eq. (1) stand for further contributions in the collision term with more than two hadrons in the final/initial channels. The transport approach (1) is fully specified by the transition rates $G^\dagger G\, \delta^4(\ldots)$ in the collision term, that describes the scattering and hadron production and absorption rates. This transport approach was found to describe reasonably well hadronic as well as dilepton data from SIS to SPS energies [16, 20].

In the present approach we propagate explicitly – apart from the baryons (cf. [16]) – pions, kaons, η's, η''s, the 1^- vector mesons ρ, ω, ϕ and K^*'s as well as the axial vector meson a_1. The high energy hadron-hadron collisions are described by the FRITIOF model [18] resulting in two excited strings. The dynamical evolution of the strings is now included explicitly. A string is characterized by the leading quark and diquark (or antiquark in the case of a mesonic string) and by the energy stored in between. The fragmentation of the strings into hadrons starts after the formation time, which is set to $\tau_F = 0.8$ fm/c (see Fig. 1). τ_F controls the baryon and meson rapidity distribution dN/dy in comparison to experimental data. The length of the strings is given by the (center of mass) collision time t_0 of the hadrons, the formation time and the velocity of the leading quarks/diquarks $\beta_i = |\vec{p}_i|/E_i$, $i = 1,2$

$$l(t) = \begin{cases} |\beta_2 - \beta_1| \cdot (t - t_0) & , \quad (t-t_0) \le \tau_F \\ \left(|\beta_2 - \beta_1| - 2 \cdot \sqrt{1 - \frac{\tau_F^2}{(t-t_0)^2}} \right) \cdot (t - t_0) & , \quad \tau_F < (t-t_0) \le t_{max} \\ 0 & , \quad (t-t_0) > t_{max}, \end{cases} \tag{3}$$

where $t_{max} = t_0 + 2\tau_F/(\sqrt{4 - |\beta_2 - \beta_1|^2})$ is the time when the string is completely hadronized. The radius of the flux tube is an unknown parameter, which will be of particular significance for the $c\bar{c}$ dissociation by strings, which we will address in section 4. The cross section of the high energy secondary interactions of the leading quarks/diquarks are treated within a simple additive quark model $\sigma(q-B) = 1/3\,\sigma(B-B)$ and $\sigma(qq - B) = 2/3\,\sigma(B - B)$.

In our simulation the production and decay of strings dominates the very early collision phase before the subsequent hadronic state of matter is formed. In Fig. 2 a characteristic representation of the hadrons and the strings during the high density phase in a central Pb + Pb collision at 160 AGeV is shown. As pointed out already in the introduction several hundred strings are formed during a central Pb-Pb collision at SPS energies. It turns out that most of them are in fact rather short due to secondary interactions of the leading quarks/diquarks. In Fig. 3 the number of strings and the averaged string length in a central Pb-Pb collision at 160GeV is shown as a function of the center of mass time.

After the hadronization many low energy rescattering processes are included. The meson-baryon and baryon-baryon collisions are treated similar to the BUU model [21]. As meson-meson channels we include the reactions $\pi\pi \to \rho, \pi\pi \to K\bar{K}, \pi\rho \to \phi, \pi\rho \to a_1$ as well as the time reversed reactions using Breit-Wigner cross sections with parameters from the literature [22] and exploiting detailed balance. For the present analysis the low energy rescattering processes do not play an essential role. Within the philosophy outlined in the introduction the production and absorption of the $c\bar{c}$ states happens in the first few fm/c of the collision before secondary particles are produced.

3 Charmonium production

Since the probability of producing initially a $c\bar{c}$ pair is very small, a perturbative approach is used for technical reasons as described in [14]. Whenever two nucleons collide a $c\bar{c}$ pair is produced with a probability factor W, which is given by the ratio of the J/Ψ to NN cross section at a center-of-mass energy $\sqrt{s}$ of the baryon-baryon collision,

$$W = \frac{\sigma_{BB \to J/\Psi + X}(\sqrt{s})}{\sigma_{BB \to BB + X}(\sqrt{s})}. \tag{4}$$

The parameterization used for the J/Ψ cross section, the rapidity and p_t distribution of the $c\bar{c}$ states is taken as in [14], which fits reasonable well the experimental data.

It is known from experiment that the Drell-Yan cross section as a hard process scales with $(A_P \times A_T)$ [2, 4, 23]. This is in contrast to most of the soft hadronic observables, like e.g. the pion multiplicity, which scale like $A_P + A_T$. This indicates a strong difference in the production of hard and soft processes in heavy ion collisions. Since the production scheme for $c\bar{c}$ is similar to the production of Drell-Yan pairs the total initial $c\bar{c}$ production cross section also scales with $A_P \times A_T$. It is important to stress that only with this stringent assumption the ratio of the J/Ψ to the Drell-Yan cross section is a direct measure for the J/Ψ suppression. We want to note that the $A_P \times A_T$ behavior of the initial $c\bar{c}$ production cross section is still a matter of

debate. As pointed out by Frankel and Frati [24] and also by Tai An et al. [25] the strong J/Ψ suppression in central Pb+Pb collisions might be explained by a nonlinear scaling of the initial $c\bar{c}$ production cross section due to initial state interactions. Such initial state interactions should also diminish the Drell-Yan cross section, which, on the other side, is not seen experimentally (for a comprehensive discussion on this issue we refer to [26]). In any case, in our approach we stay with the same scaling behavior and investigate the subsequent absorption of $c\bar{c}$ pairs on baryons and strings. For that reason we emphasize that the $A_P \times A_T$ scaling of the initial $c\bar{c}$ production is an input of our calculation and not a result. To implement this scaling we separate the production of the hard and soft processes: The space-time production vertices of the $c\bar{c}$ pairs are calculated before every run neglecting the soft processes. After that we follow the motion of the Charmonium pairs within the full hadronic background by propagating it as a free particle. Again, only with this concept the $A_P \times A_T$ dependence of the $c\bar{c}$ production can be reproduced in a hadronic transport simulation.

4 $c\bar{c}$ dissociation

The $c\bar{c}$ state as a rather heavy hadronic particle and a result of a hard process is formed immediately in comparison to the soft particle production from string fragmentation. Thus first of all the $c\bar{c}$ states move not in a hadronic environment but in an environment of color electric strings of 'wounded' nucleons (see Fig. 2). As motivated in the introduction and in ref.[19] we now assume that a $c\bar{c}$ state immediately dissociates whenever it moves into the region of the color electric field of a string. In this sense strings are completely black for $c\bar{c}$ states. It was found in [19] that the additional force acting on the charm quarks is given by $2 \times \sigma \approx 2\, GeV/fm$, where σ denotes the phenomenological string constant of a chromoelectric flux, which is sufficient to immediately break up a $c\bar{c}$ state. One can also argue that the field energy density contained in a string is given by $\sigma/(\pi R_S^2)$. For $R_S \approx 0.3\, fm$ one accordingly has a local high color electric energy density of $\approx 4\, GeV/fm^3$, which substantially screens the binding potential of the Charmonium state [1].

For practical reasons the dissociation by a string is modeled when the center of mass of the $c\bar{c}$ state is located inside the string. The length of the strings is given by eq. (3), while the string radius R_s is an unknown parameter. Absorption by strings spanned between the parent particles of the $c\bar{c}$ pair are excluded, since this effect already is included in the production cross section.

Additionally, the $c\bar{c}$ pair may be destroyed by collisions with incoming baryons. For the collisions with baryons we use the minimum distance concept described in Ref. [21]. For the actual cross sections employed we assume that the $c\bar{c}$ pair initially is produced in a color-octet state and immediately picks up a soft gluon to form a color neutral $c\bar{c} - g$ Fock state [7] (color dipole). This extended configuration in space is assumed to have a 6 mb absorption cross section in collisions with baryons ($c\bar{c} + B \rightarrow \Lambda_c + \bar{D}$) as in Refs. [3, 10, 7] during the lifetime τ of the $c\bar{c} - g$ state, for which we adopt $\tau = 0.3$ fm/c as suggested by Kharzeev [7]. One also has to specify the absorption cross sections of the formed resonances J/Ψ on baryons. For simplicity we use 3 mb

following Refs. [27, 14].

5 Results

In proton-nucleus collision the $c\bar{c}$ dissociation by strings is practically negligible. The absorption is dominated by $c\bar{c}$-baryon collisions so that the proton nucleus data allow to fix this absorption cross section. In Fig. 4 we show our results for the J/Ψ survival probability $S^{J/\Psi}$ using 6 mb for the absorption cross section of the $c\bar{c}$-pairs on nucleons in comparison to the data [3]. The experimental 'survival probabilities' $S^{J/\Psi}_{exp}$ in this figure as well as in the following comparisons are defined by the ratio of experimental J/Ψ to Drell-Yan cross sections as

$$S^{J/\Psi}_{exp} = \left(\frac{B_{\mu\mu}\sigma^{J/\Psi}_{AB}}{\sigma^{DY}_{AB}|_{2.9-4.5\ \mathrm{GeV}}} \right) \Big/ \left(\frac{B_{\mu\mu}\sigma^{J/\Psi}_{pd}}{\sigma^{DY}_{pd}} \right), \tag{5}$$

where A and B denote the target and projectile mass while $\sigma^{J/\Psi}_{AB}$ and σ^{DY}_{AB} stand for the J/Ψ and Drell-Yan cross sections from AB collisions, respectively, and $B_{\mu\mu}$ is the branching ratio of J/Ψ to dimuons. The theoretical ratio is defined as

$$S^{J/\Psi}_{theor} = \frac{M_{J/\Psi}}{N_{J/\Psi}}, \tag{6}$$

where $N_{J/\Psi}$ is the multiplicity of initially produced J/Ψ's while $M_{J/\Psi}$ is the multiplicity of J/Ψ's that survive the hadronic final state interactions.

In Fig. 4 results are shown for two different string radii $R_S = 0.1 fm$ and $R_S = 0.4 fm$. The difference of the curves is rather small, which indicates the small effect of dissociation by strings. For p + U and $R_S = 0.4 fm$ only 2% of the J/Ψ are absorbed by strings. This is completely different for heavy ion collisions, where the absorption on strings becomes a much more important effect.

To compare our results for S + U and Pb + Pb to the NA38 and NA50 data, the experimental trigger conditions must be included. In these experiments only events are recorded with a $\mu^+\mu^-$ pair of invariant mass $M \geq 1.5$ GeV. This trigger condition is obtained by

$$\frac{d\sigma^{\mu\mu}_{theor}}{E_T} = 2\pi N_0 \int_0^\infty bdb\ \frac{dN}{dE_T}(b)\ \sum_i W^{\mu\mu}_i(b), \tag{7}$$

where $W^{\mu\mu}_i(b)$ are the weights for produced $\mu\mu$ pairs within the experimental cuts. N_0 is a normalization factor to adjust to the experimental number of events. We take the same weight factors $W^{\mu\mu}_i(b)$ as in [14] which reasonably reproduce the experimental E_t distribution as shown in [14].

Qualitatively the results are not changed by this procedure. In Fig. 5 our results are shown for S + U and Pb + Pb as a function of the transverse energy and for four different string radii. A strong dependence on the string radius R_S is observed and $R_S = 0.2 fm$ gives the best fit to experimental data [4, 5]. With this string radius 40% of the absorbed J/Ψ's are dissociated by strings in central collisions of Pb + Pb as shown in Tab. 1.

$R_S[fm]$	A_{tot}	A_B	A_S
0.1	0.65	0.53	0.12
0.2	0.74	0.44	0.30
0.3	0.82	0.36	0.46
0.4	0.88	0.29	0.59

Table 1: Total J/Ψ absorption probability $A_{tot} = 1 - S^{J/\Psi}_{theor}$, absorption by baryons A_B and by strings A_S for different string radii in a central Pb + Pb collision as obtained in the HSD approach.

6 Summary

In this work we have addressed the question of $c\bar{c}$ absorption in relativistic heavy ion collisions in the microscopic transport approach HSD. Of particular interest was the effect of the prehadronic phase, which in the HSD model is described by independent strings. In principle the comover absorption scenario could be included in addition. However, since most of the $c\bar{c}$ pairs are already absorbed by strings and baryons in the early stage of the reaction, the effect of comovers is expected to be much less than found in ref. [14].

The dissociation mechanism by strings was treated in a simple geometrical picture. Whenever a $c\bar{c}$ pair moves into a string it dissociates and forms $D\bar{D}$ mesons. Strings are completely 'black' for $c\bar{c}$ states. This stringent condition is a first ansatz to investigate the effect of the $c\bar{c}$ dissociation by strings. Better theoretical foundations of the dissociation mechanism of charmonium (J/Ψ and ψ') and preresonant states ($c\bar{c}g$) are definitely needed to improve the understanding of this geometrical picture.

We found that the absorption by strings plays is an important effect in the first few fm/c of the collision phase before secondary particles are produced. Adopting a string radius of $0.2fm$ we got a qualitative agreement with p+A data and the NA38 and NA50 data. This radius seems to be rather small, but for two reasons it should be seen as a lower bound for R_S. First of all, we have assumed that the strings are completely black for $c\bar{c}$ states, and secondly it dissociates whenever it moves into the region of the color electric field of a string. With the requirement that the total $c\bar{c}$ state should be inside the string when the dissociation process starts, one should add the $c\bar{c}$ radius to our value of R_S. This would give a string radius of $\tilde{R}_S \approx 0.4 - 0.5fm$.

With our results we can estimate the fraction of the reaction volume which is filled by the flux tubes of the strings. In the very central region with 1 fm thickness along the longitudinal direction in the cms frame, we get $N_S \sim 420$ strings in a central Pb + Pb collision generated within the HSD approach. The averaged string length $< l >\sim 0.5fm$ is rather small due to secondary interaction of the leading quarks. Only a small amount of strings reaches a length above 1.2 fm. With these results we get a string volume of

$$V_s = \pi R_S^2 \cdot < l > \cdot N_S \approx \begin{cases} 65fm^3, & R_S = 0.3fm \\ 115fm^3, & R_S = 0.4fm \end{cases} . \qquad (8)$$

The total volume in this central cylinder is given by

$$V_t = \pi R_{Pb}^2 \cdot 1fm \approx 130 fm^3, \tag{9}$$

where $R_{Pb} = 6.6\,fm$ is the radius of the Pb nuclei. Comparing V_s and V_t illustrates that 50-75% of the central volume in an ultrarelativistic heavy ion collision is filled by strings in the first few fm/c assuming a string radius of 0.3 - 0.4 fm. The probability for a $c\bar{c}$ pair to pass the central region thus is rather small. This explains the strong dependence of the J/Ψ results on the string radius.

We conclude our study by noting that $c\bar{c}$ dissociation in the prehadronic phase seems to be a dominant and likely charmonium absorption process in relativistic heavy ion collisions. The qualitative behavior of the proton-nucleus and nucleus-nucleus data can be described within this picture. We note that the sudden jump in the J/Ψ suppression for Pb + Pb suggested by the data for $E_T \approx 50\,GeV$ in Fig. 5 cannot be described in our dynamical model as in Ref. [14] based on string and hadron dynamics (cf. also [26] for a recent overview), because the predicted suppression within our approach is always a rather smooth function of atomic number and centrality of the collision. If confirmed experimentally, this might indicate a new phase with other degrees of freedom (partons) and reaction channels possibly related to a deconfined QGP formation [28].

References

[1] T. Matsui and H. Satz, Phys. Lett. B 178 (1986) 416.

[2] NA38 Collaboration, C. Baglin et al., Phys. Lett. B 270 (1991) 105; Phys. Lett. B 345 (1995) 617; S. Ramos, Nucl. Phys. A 590 (1995) 117c.

[3] NA50 Collaboration, M. Gonin et al., Nucl. Phys. A 610 (1996) 404c;

[4] NA50 Collaboration, F. Fleuret et al., in '97 QCD High Energy Hadronic Interactions, ed. by Tran Thanh Van, Editions Frontiéres, (1997) 503

[5] NA50 Collaboration, L. Ramello, to appear in the Proc. of the Quark Matter '97 Conference.

[6] C. Gerschel and J. Hüfner, hep-ph/9802245.

[7] D. Kharzeev, Nucl. Phys. A 610 (1996) 418c. J. Hüfner and BZ. Kopeliovitch, Phys. Rev. Lett. 76 (1996) 192

[8] J. P. Blaizot and J. Y. Ollitrault, Phys. Rev. Lett. 77 (1996) 1703; Nucl. Phys. A 610 (1996) 452c.

[9] C.-Y. Wong, Nucl. Phys. A 610 (1996) 434c.

[10] C. Gerschel and J. Hüfner, Z. Phys. C 56 (1992) 71; C. Gerschel, Nucl. Phys. A 583 (1995) 643.

[11] S. Gavin and R. Vogt, Nucl. Phys. B 345 (1990) 104; S. Gavin, H. Satz, R. L. Thews, and R. Vogt, Z. Phys. C 61 (1994) 351; S. Gavin, Nucl. Phys. A 566 (1994) 383c.

[12] S. Gavin and R. Vogt, Nucl. Phys. A 610 (1996) 442c; Phys. Rev. Lett. 78 (1997) 1006.

[13] A. Capella, A. Kaidalov, A. Kouider Akil, and C. Gerschel, Phys. Lett. B 393 (1997) 431.

[14] W. Cassing and E. L. Bratkovskaya, Nucl. Phys. A 623 (1997), 570

[15] N. Armesto and A. Capella, hep-ph/9705275.

[16] W. Ehehalt and W. Cassing, Nucl. Phys. A 602 (1996) 449.

[17] H. Satz, hep-ph/9711289; D. Kharzeev and H. Satz, Phys. Lett. B 334 (1994) 155.

[18] B. Anderson, G. Gustafson, Hong Pi, Z. Phys. C 57 (1993) 485.

[19] S. Loh, C. Greiner, and U. Mosel, Phys. Lett. B 404 (1997) 238.

[20] W. Cassing, W. Ehehalt, and C. M. Ko, Phys. Lett. B 363 (1995) 35, W. Cassing, W. Ehehalt, and I. Kralik, Phys. Lett. B 377 (1996) 5, E. L. Bratkovskaya, W. Cassing and U. Mosel, Z. Phys. C 75 (1997) 119, E. L. Bratkovskaya and W. Cassing, Nucl. Phys. A 619 (1997) 413

[21] Gy. Wolf, G. Batko, W. Cassing, U. Mosel, K. Niita, and M. Schäfer, Nucl. Phys. A 517 (1990) 615, Gy. Wolf, W. Cassing, U. Mosel, Nucl. Phys. A 552 (1993) 459.

[22] Particle Data Booklet, Phys. Rev. D 50 (1994) 1173.

[23] C. Lourenço, PhD Thesis, Lisbon 1995 (unpublished).

[24] S. Frankel and W. Frati, hep-ph/9710532; hep-ph/9710022

[25] Tai An, Chao Wei Qin and Yao Xiao Xia, hep-ph/9701207

[26] D. Kharzeev, nucl-th/9802037

[27] D. Kharzeev and H. Satz, Phys. Lett. B 366 (1996) 316.

[28] D. Kharzeev, M. Nardi and H. Satz, hep-ph/9707308

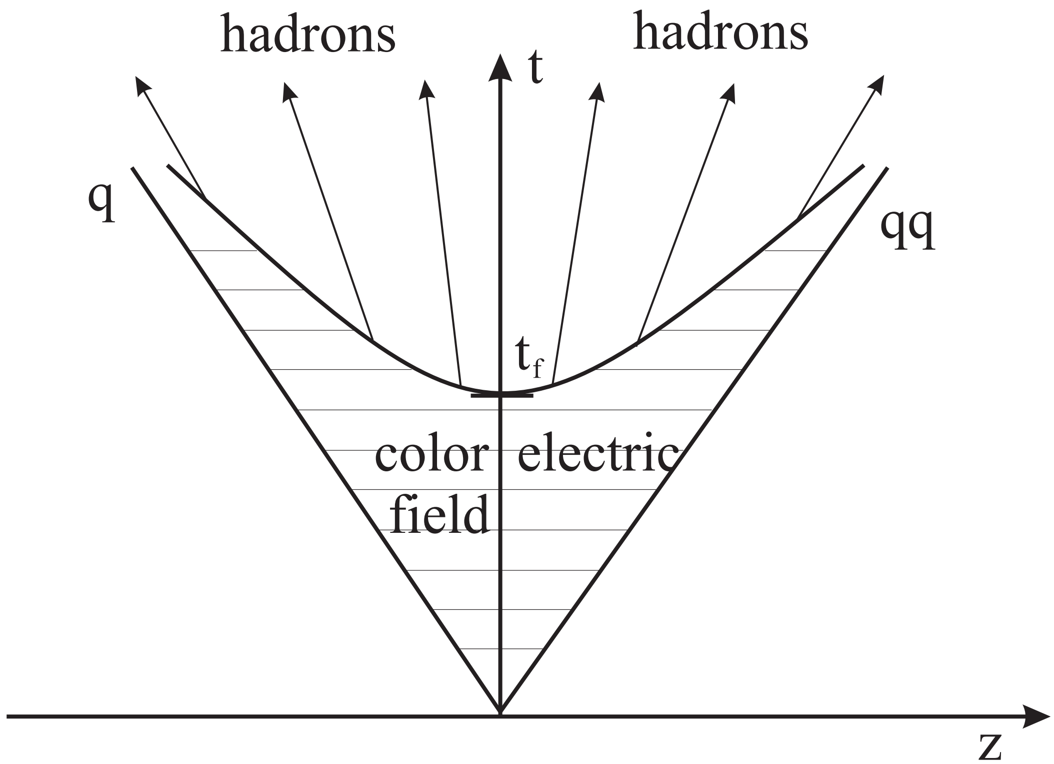

Figure 1: Dynamical evolution of a baryonic string. The fragmentation starts after the formation time t_f.

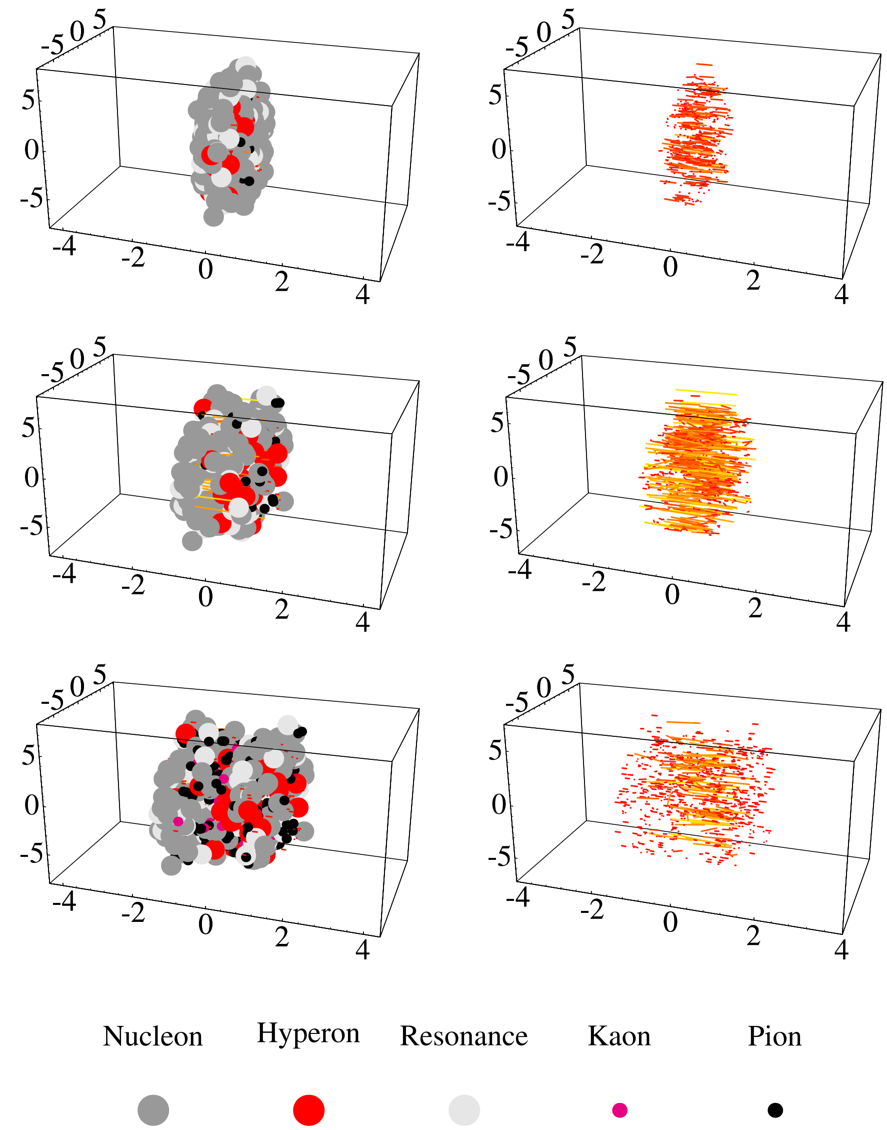

Figure 2: Graphical representation of the hadrons (left) and the strings (right) during the high density phase in a central Pb + Pb collision at 160 AGeV in the center of mass system. Three time steps are shown at $t_{cm} = (4.4, 5.0, 5.6)$ fm/c (see next figure); the axis labels are given in fm.

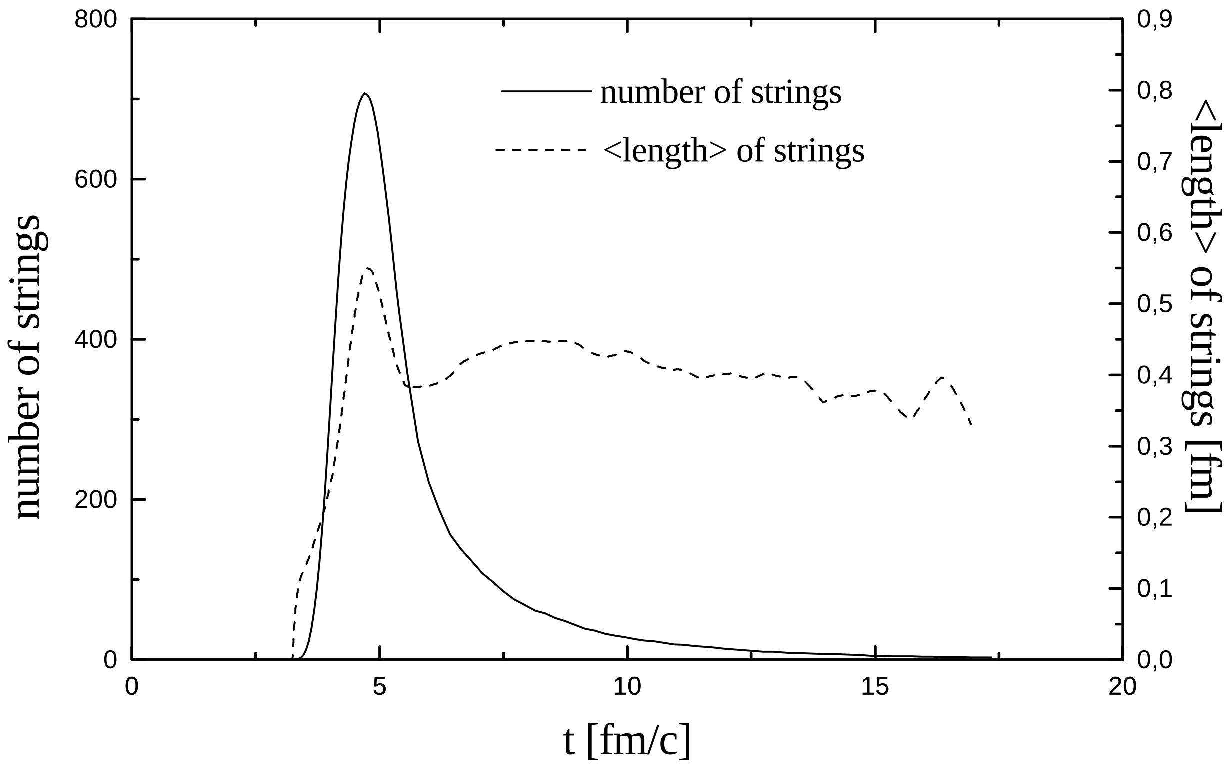

Figure 3: Number of strings and average string length in a central Pb-Pb collision at 160GeV as a function of time in the nucleus-nucleus cms.

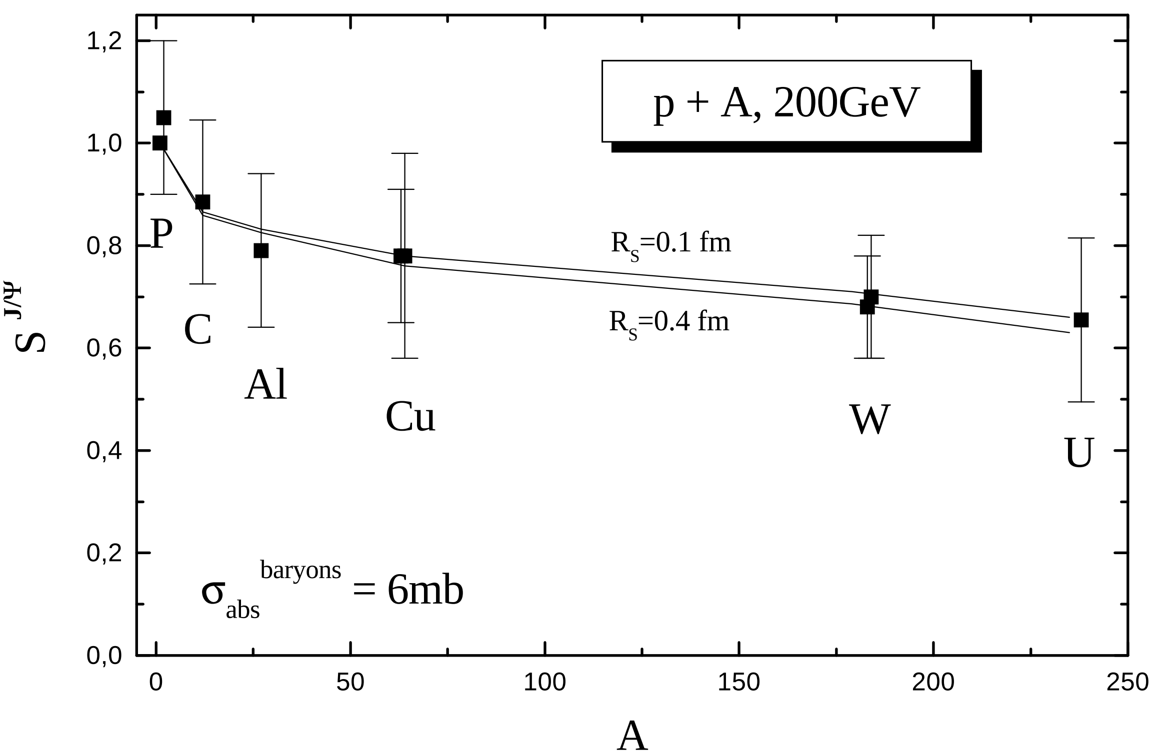

Figure 4: The J/Ψ survival probability $S^{J/\Psi}$ for minimum bias p + A reactions at 200 GeV assuming a 6 mb cross section for the $c\bar{c}$ absorption on baryons including $c\bar{c}$ dissociation on strings for two different string radii, 0.1 fm and 0.4 fm in comparison to the experimental data from [3].

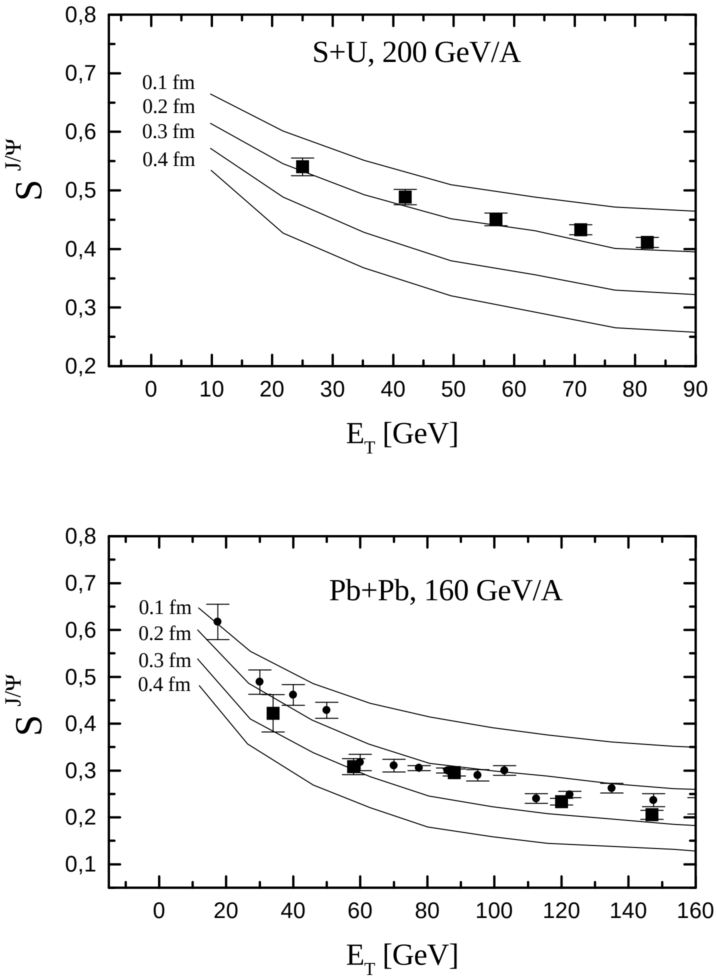

Figure 5: The J/Ψ survival probability $S^{J/\Psi}$ for S + U at 200 AGeV (upper part) and Pb + Pb at 160 AGeV (lower part) as a function of the transverse energy in comparison to the experimental data from [4]. The circles in the lower part are the new NA50 data from [5]. Results are shown for four string radii from $R_S = 0.1$ fm to $R_S = 0.4$ fm.